CE 3500: Homework 5
Solutions

Problem 1. *Design a rigid pavement by specifying the slab thickness, given the following information: daily roadway volume consists of 25,000 passenger vehicles (two axles with a load of ~~2000~~ 2 kips each) and 10,000 semi-tractor trailers (assume each semi has a single axle with an ~~8000~~ 8 kip load and two tandem axles, each with a 20 kip load), and is expected to grow by 3% per year. The subbase elastic modulus is 100,000 psi; the roadbed soil resilient modulus is 10,000 psi; the concrete elastic modulus and modulus of rupture are 5,000,000 psi and 650 psi, respectively; the load transfer coefficient is 3.2; and the overall standard deviation is 0.29. The pavement is saturated with moisture 5% of the time, and it takes a week for water to drain from beneath the pavement. Bedrock lies 5 ft below the surface of the road. Design the pavement to last 15 years (expecting its PSI to degrade from 4 to 2.5 in that time) with 95% reliability, assuming that the subbase is 10 inches thick.*

First we calculate the ESAL loading. Assuming a 10-inch slab thickness, the rigid pavement equivalency factors for 2 kip single axles, 8 kip single axles, and 20 kip tandem axles are 0.0002, 0.032, and 0.204, respectively. Furthermore, the growth factor is $G_{rn} = [(1+r)^n - 1]/r = [(1.03)^15 - 1]/0.03 = 18.6$. The ESAL loading due to these vehicles is thus

Passenger vehicles: $0.5 \times 18.6 \times 25000 \times 365 \times 2 \times 0.0002 = 33,900$

Semis, single axle: $0.5 \times 18.6 \times 10000 \times 365 \times 1 \times 0.032 = 1,090,000$

Semis, tandem axles: $0.5 \times 18.6 \times 10000 \times 365 \times 2 \times 0.204 = 13,800,000$

Adding these, the total ESAL load is $15,000,000$. Furthermore, based on the drainage tables, the coefficient of drainage is $C_d = 1.00$ and the design serviceability loss is $4 - 2.5 = 1.5$. Using the nomographs (see figures online), we estimate $k_\infty \approx 800$ psi, $k \approx 1100$ psi, and a slab thickness of 10 inches.

Problem 2. *Estimate the number of vehicle-pedestrian crashes per year at an urban signalized intersection between two roads, each with an AADT of 5000 vehicles and a total of 750 pedestrians crossing per day. There are four alcohol sales establishments within 1,000 feet of the intersection (CMF 1.12) as well as two bus stops (CMF 2.78). The safety performance function for vehicle-pedestrian crashes at urban four-leg signalized intersections with equal volume on each approach is*

$$N_{SPF} = \exp\left(-9.45 + 0.40\ln(AADT) + 0.45\ln(PedVol)\right)$$

where $AADT$ is the total $AADT$ on all approaches and $PedVol$ is the total number of pedestrian crossings.

The expected average crash frequency is $EACF = N_{SPF} C \prod CMF$ Since we do not have historical data to calibrate with, we assume $C = 1$. N_{SPF} is given by

$$N_{SPF} = \exp\left(-9.45 + 0.40\ln(10000) + 0.45\ln(750)\right) = 0.062$$

so

$$EACF = 0.062 \times 1.12 \times 2.78 = 0.19$$

crashes per year.